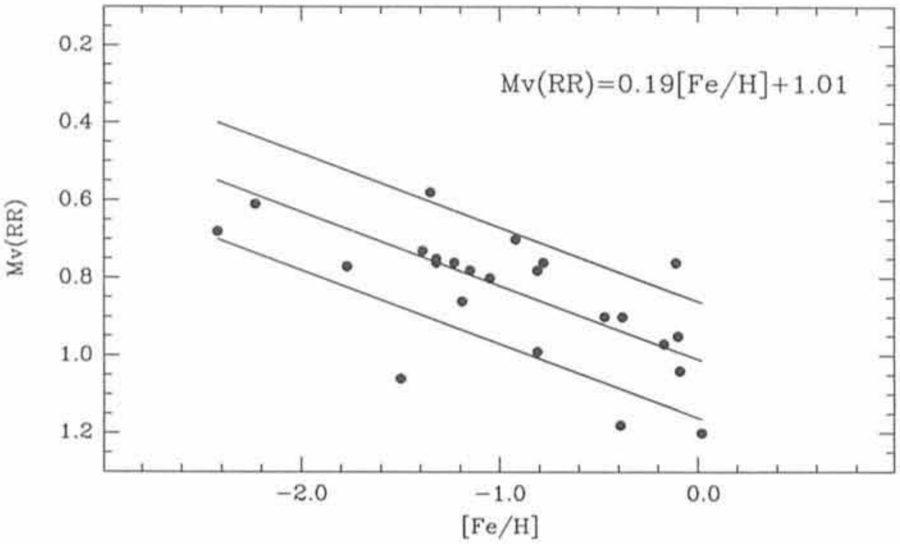

Figure 5: *Summary of the RR Lyrae absolute magnitude determinations obtained from infrared data (IF method, or SB plus V−K colours). The solid lines define the range $\Delta M_V = \pm 0.15$ mag around the ridge line defined in the text.*

~0.16 using slightly different values of M_V(RR) for a few very metal-poor and very metal-rich stars, and values ranging from 0.20 to 0.38 have been found with a number of methods and assumptions, as reviewed and discussed by Buonanno et al. (1990).

The use of the above relationship to estimate globular cluster ages leads to 16 and 19 Gyrs for metal-rich and metal-poor clusters respectively on the assumption that [CNO/Fe] = solar, and to slightly lower values depending on the amount and degree of metallicity dependence of O enhancement, if any.

The obvious further step with respect to the work done so far on field stars is to extend this type of analysis to globular cluster RR Lyraes. Since in a given cluster RR Lyraes are all at the same distance and have the same metal abundance (with the exception of ω Cen), the study of a sufficiently large number of them can provide a more accurate determination of the average absolute magnitude in each cluster and of its dependence on metallicity. Globular cluster variables are however much fainter than their field counterparts, and the observations are correspondingly more difficult and time-consuming. In particular CORAVEL, in its present configuration, cannot be used for RR Lyraes fainter than V = 12.5–13 mag, while the brightest RR Lyraes in globular clusters at minimum light are V ≥ 13.5. For this reason very few results have appeared on this topic (Cohen and Gordon, 1987, Liu and Janes, 1990), although considerable effort is being devoted to it. We have started a programme on the RR Lyrae variables in M4, and have collected BVRIJHK photometry and CASPEC high-resolution spectra for 4 variables, covering the entire pulsation cycles. The data are presently being analysed and will be the subject of a forthcoming paper.

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Galaxy Photometry with SEST: How Big Are Galaxies at Millimetric Wavelengths?

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Introduction

The information currently available on the electromagnetic emission of normal galaxies at long wavelengths (λ = 100 ÷ 3000 μm) is still quite sparse and serious discrepancies are found among different observations. Only very recently the improvement in instrument sensitivity has allowed exploration of the galaxy submm-mm continuum. Data on millimetre continuum emission of galaxies are mainly confined to active galaxies (both AGNs and starburst galaxies), because of their enhanced nuclear emission, while only a handful of normal spirals have been observed so far at these wavelengths (Chini et al., 1986, Stark et al., 1988; Eales et al., 1989).

The IRAS surveys have shown that the far-IR spectra of late-type galaxies are mainly of thermal origin, due to dust grains present in their interstellar medium. However, far-IR measurements are not enough by themselves to estimate the overall dust content, since an important fraction (often more than ~ 50 %) of dust is expected to be colder than 20 K and therefore its emission lies at $\lambda > 100$ μm. Therefore, in order to study the characteristics of cold dust, which are important to understand both galactic evolution and star-formation processes, submm-mm photometry is needed. The continuum flux in this spectral range is linearly related to the temperature, mass and opacities of dust grains, and its measurement provides an alternative way to estimate these parameters.

The exploitation of the high sensitivity achievable by bolometer detectors (Kreysa, 1990), together with the high spatial resolution of large antennas such as SEST (with a FWHM of 24″), is expected to strongly improve our knowledge of the galaxy spectra and of the total amount of dust present in the interstellar medium, its spatial distribution within the galaxies and its relationship with other basic components, such as the atomic and molecular gas, the stars, etc.

We have started an observational programme whose aim is the investigation of the 1.2-mm continuum emission of a complete sample of galaxies selected from the IRAS Point Source Catalogue, for which optical photometry and spectroscopy are partially available. The sample comprises 61 galaxies with a 60-μm flux above 2 Jy in the sky region delimited by the equatorial coordinates $21h < R.A. < 5h$ and $-22.5° < \delta < -32°$. The completeness of the sample ensures that unbiased estimates of the crucial parameters (such as the average mm to far-IR wavelength flux ratio and the bivariate luminosity distributions) could be obtained. This will eventually allow the determination of the local luminosity functions of galaxies at $\lambda = 1$ mm. Several important applications of this analysis can be envisaged. Let us mention two among others.

(1) A reliable determination of the galaxy local luminosity at $\lambda = 1$ mm, added to observations of the extragalactic background being currently performed by the COBE satellite, and to ground-based millimetric surveys, planned in the near future with the use of bolometer arrays, may tell us something new and fundamental about the cosmic evolution of galaxies and of their dust content (Franceschini et al., 1990).

(2) A better knowledge of galaxy continuous spectra in this energy domain will allow to refine the estimate of the contribution of known discrete sources to the cell-to-cell fluctuations of the Cosmic Microwave Background (CMB) at small and intermediate angular scales. Franceschini et al. (1989), on the basis of theoretical models of dust emission spectra of galaxies, have shown that such contribution may be significant even at ~ 1 mm, that is near the peak of the CMB spectrum. Eventually, the detection of any intrinsic anisotropies of the CMB would crucially rely on a correct subtraction of the normal galaxy contribution.

A successful observational run performed last year at SEST has already provided us with some reliable detections and upper limits for half of the sample objects falling in the δ range from $-22°.5$ and $-26°.5$. We briefly report here on results of these observations and on problems raised by a comparison with previously published data.

Observations with the SEST Telescope

The observations have been performed during September 1990 using the 15-m SEST telescope at La Silla equipped with the ^{3}He bolometer of the MPIfR (Max-Planck-Institut für Radioastronomie).

The filter set coupled to the atmospheric transmission window provides an effective wavelength around 1.25 mm. The beam size is 24″ (HPBW).

Source position was found by pointing a nearby radio-loud quasar with strong millimetric fluxes. Pointing accuracy was most of the time better than 2″ and was checked each half an hour.

Beam-switching is achieved by a chopper wheel located in the receiver cabin, switching the beam ON-OFF the source. This, coupled to the nodding of the telescope, results in a three-beam technique which allows comparison between the source signal and that from two opposite empty regions of sky. The chop throw was set to be 70″, which is larger than the optical diameter of the sample galaxies. Each source has been observed n·200 seconds with n depending on the expected 1.2 mm intensity. The latter has been approximately evaluated extrapolating the IRAS 100 μm flux using a thermal spectrum with an opacity spectral index between 1 and 2.

Atmospheric transmission has been monitored by frequent skydips. Uranus has been used as primary calibrator by assuming a weighted effective temperature at this wavelength of 93±1 K. Several quasars have been used as secondary calibrators mainly to detect sky variations during the observations. The overall accuracy on the detected fluxes was good (~ 10 %) because of the optimum atmospheric conditions.

Twenty-eight objects have been observed, for 12 of which reliable fluxes (better than 3 sigma values) have been obtained. The observed values of the millimetre flux have been corrected for the overall system response and K-correction.

For each source the ratio $\frac{f_{1.25mm}}{f_{100\mu m}}$ has been computed. The IRAS fluxes have been taken from the IRAS Point Source Catalogue, slightly modified to account for colour and K-corrections.

The Average mm to Far-IR Flux Ratio

Histograms of the ratio $\frac{f_{1.25mm}}{f_{100\mu m}}$ are reported in Figure 1. Panel (a) refers to those data without any aperture corrections. A technique of *survival analysis* has been used to make full use of the information content in the upper limits to the 1.25 mm fluxes. In this way we have estimated an average flux ratio $\frac{f_{1.25mm}}{f_{100\mu m}} = (2.02 \pm 0.36)\ 10^{-3}$.

Right-hand side panels of Figure 1 also report flux ratios derived from data collected with the IRAM 30-m antenna, whose results have already been reported in this Journal (see No. 61 – September 1990, p. 44). We find in this case $\frac{f_{1.25mm}}{f_{100\mu m}}$ $(1.51 \pm 0.12)\ 10^{-3}$ (panel (b)).

The same analysis has been applied to the Cini et al.'s (1986) data on 26 spiral galaxies observed with the IRTF 3-m telescope. The histogram of their mm to far-IR flux ratios is plotted in Figure 2. The survival analysis provides in this case a substantially higher value for the average ratio $\frac{f_{1.3mm}}{f_{100\mu m}} = 1.4\ 10^{-3}$.

An opposite indication comes from observations at 350, 450, 800 and 1100 μm performed by Eales et al. (1989) on a few nearby galaxies. In contrast with Chini et al.'s results, these authors claim that the energy distribution in the far-IR/submillimetric range is well fitted by a thermal emission of warm dust at 30–50 K, which implies a substantially lower value for the average mm to far-IR flux ratio. Indeed, by extrapolating their model to 1.25 mm, we find in this case a value smaller by at least a factor of 2 than that implied by our observations. The discrepancy is even larger with Chini et al.'s results (more than a factor of 10 in this case).

Some other sub-mm observations are not even commensurate with ours. Stark

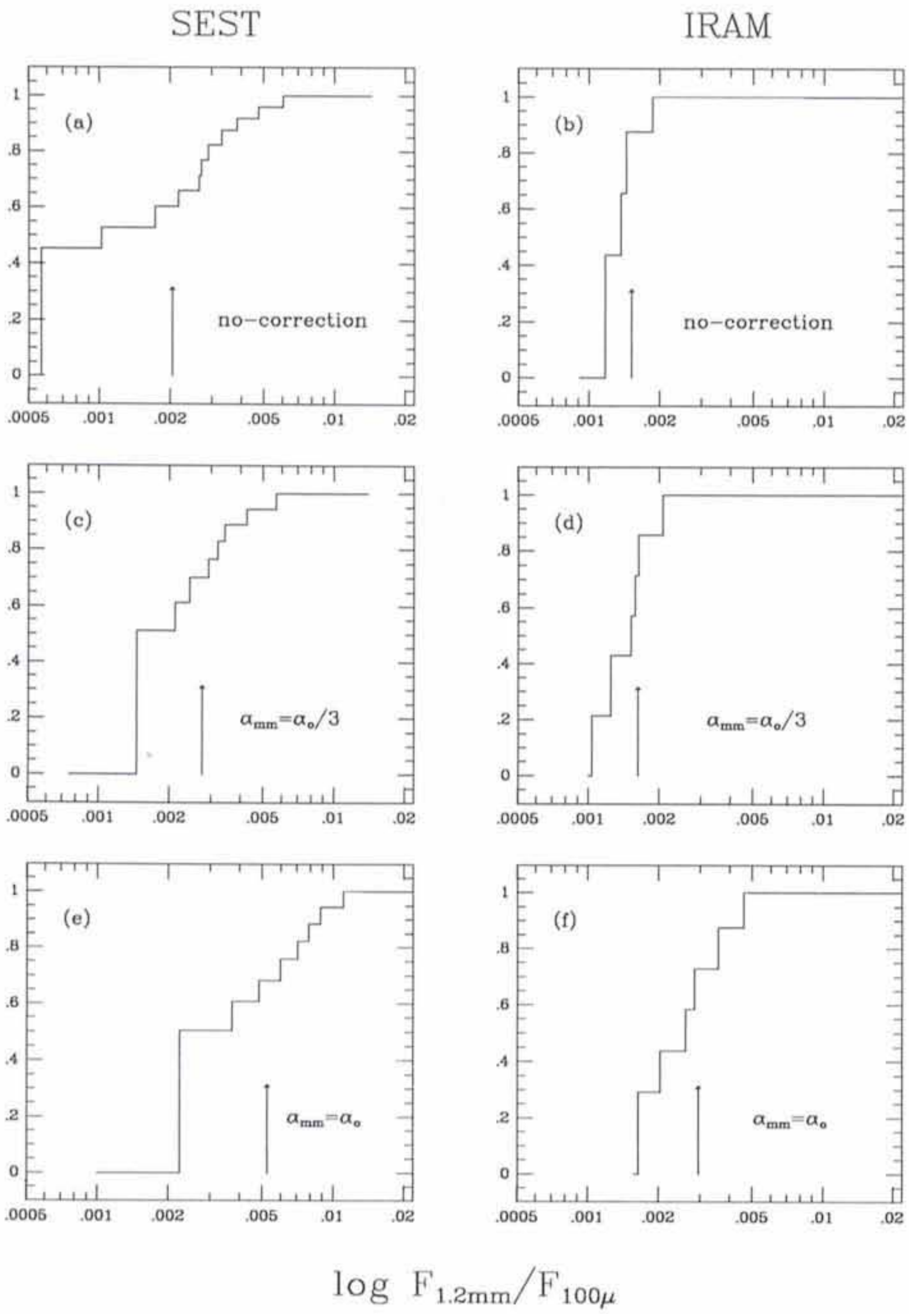

Figure 1: *(a) The cumulative probability distributions of the* $\frac{f_{1.25mm}}{f_{100\mu m}}$ *ratio for the SEST (left-hand-side panels) and IRAM samples (right-hand-side panels). The distributions have been reconstructed with detection-and-bound techniques. Panels (a) and (b) report the distributions based on fluxes without any aperture corrections; panels (c) and (d) those based on fluxes corrected under the hypothesis that the mm light profile has a scale-length* α_{mm} *equal to one third of the optical one,* α_o*; panels (e) and (f) refer to the hypothesis that mm light profiles follow those in the optical. The arrows mark the average values.*

et al. (1988) mapped four Virgo spirals at 160 and 360 μm at a spatial resolution of ~ 45", but with a poor S/N ratio at 360 μm. Thronson et al. (1987) observed only the very centre of large active galaxies at 1.3 mm, sampling a too small portion of the entire galaxy disks. Therefore, they probably lost most of the millimetric flux.

To conclude, galaxy spectra in this spectral domain, hence the total amount of dust, are uncertain by up to one order of magnitude. We will briefly discuss possible origins of this large discrepancy and suggest how further investigations might be helpful in elucidating this question. Beam-aperture corrections may contribute to explain these discrepancies. Unfortunately, the lack of knowledge of the spatial extension of galaxies at long wavelengths hampers a precise estimate of this effect. Moreover, in some ON-OFF observations, the beam separation was too small in comparison with the larger optical dimensions of the objects, and only a gradient in the emission has probably been measured.

Aperture Corrections to mm Fluxes

In order to consider the whole effect of a gaussian beam on the detected fluxes, a convolution of the beam-shape with the light profile of the galaxy millimetric emission must be done. We suppose that the millimetric light profile is exponential with scale-length α_{mm}. We have considered the following two hypotheses:

(1) The radial distribution of cold dust closely follows that of the blue light. In this case the millimetric scale-length α_{mm} is equal to that in blue light, α_o. The corresponding average flux ratios after correction for aperture are $\frac{f_{1.25mm}}{f_{100\mu m}}$ = 5.28 10^{-3} for the SEST sample $\frac{f_{1.25mm}}{f_{100\mu m}}$ = 2.92 10^{-3} for the IRAM. Therefore, on average the detected fluxes must be corrected by a factor greater than 2 (see Fig. 1 panels (e) and (f)).

(2) the second hypothesis considered here takes into account that the millimetric scale length is one third of the optical one: $\alpha_{mm} = \frac{1}{3}\alpha_o$. In this case, we find as mean ratios: $\frac{f_{1.25mm}}{f_{100\mu m}}$ = 2.76 10^{-3} for the SEST sample $\frac{f_{1.25mm}}{f_{100\mu m}}$ = 1.51 10^{-3} for the IRAM sample. In this case a large fraction of the millimetric flux would have been detected (Fig. 1 panels (c) and (d)).

From these simple considerations we have shown that the millimetric fluxes, hence the amount of cold dust in galaxies, are crucially dependent on the size of the objects at millimetre wavelengths.

It is not clear how far we can compare these results with the data obtained by Chini et al. on large spirals (1986). The optical dimensions of their objects often exceed that of the beam width and in some cases this is also true for the chop throw. From this point of view, they could have underestimated to some extent the millimetric fluxes. On the other hand, there is evidence that most of the fluxes reported in the IRAS Point Source and Small Extended Source Catalogues are significantly underestimated for extended objects (see Rice et al., 1988; Young et al., 1989). So, their mean ratio $\frac{f_{1.25mm}}{f_{100\mu m}}$ could have been somewhat overestimated.

The Far-IR Extension of Normal Galaxies

The obvious solution to the problem of estimating galaxy broad-band spectra in the mm range will be to use arrays of bolometers, when available (Cunningham and Gear, 1990), to cover the entire

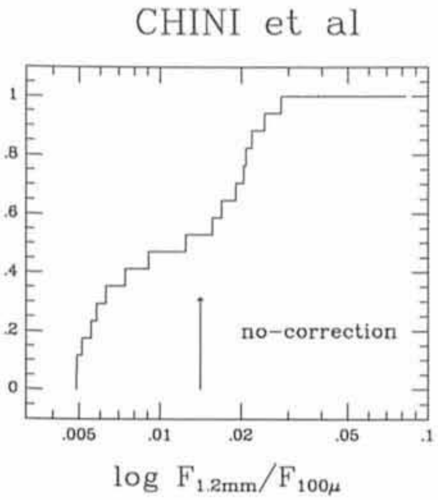

Figure 2: *The same as Figure 1 for the Chini et al.'s results.*

optical extension of the galaxy. The use of large enough beam apertures, some times larger than the diffraction limit, with current mm telescopes is discouraged by the dramatic increase of the sky noise with respect to diffraction-limited observations.

The alternative is to obtain information on the spatial distribution of light emission at submm-mm wavelengths by suitably mapping some bright nearby sources. This will be the goal of our next observing runs at La Silla.

Let us briefly discuss currently available information on the subject.

A direct comparison of optical and far-IR profiles (at $\lambda = 50$ and 100 μm) has been done by Wainscoat et al. (1987) on three nearby edge-on spirals using the IRAS CPC (Chopped Photometric Channel) instrument. Unfortunately, edge-on galaxies do not allow a detailed study of the radial disk structure. However, a comparison between the far-IR emission along the major axis can be performed with the optical old-disk light. From their study of NGC 891 it seems that the 100-μm emission is more extended than the 50-μm one. They suggest that the cold diffuse interstellar component dominates with respect to the optical emission at distances beyond 9 kpc from the centre. For the other two objects (NGC 4565 and NGC 5907) similar far-IR and optical light profiles can be inferred from these observations. This seems to indicate that the cold dust emission at mm wavelengths might be quite extended with respect to the warm component and the optical emission, although IRAS maps at large radii are too noisy for any definitive conclusion to be drawn.

For a sample of large galaxies partially resolved by IRAS (Rice et al., 1988) the mean ratio of the far-IR (60 μm) D_{IR} to blue-light D_B isophotal diameters turns out to be 0.98 ± 0.25, which means that on average galaxies have far-IR extensions comparable to their optical sizes, quite in agreement with previously mentioned results. In this case, however, the observed mean of the ratio of the effective far-IR aperture diameter A_e (which include half of the galaxy's light) to the isophotal radius for 11 objects of this sample, turns out to be almost half of that of the blue light: $< (A_e/D)_{IR} > \sim 0.17$, $< (A_e/D)_B > \sim 0.35$. This difference indicates that the IR emission could be more centrally concentrated than that of the blue light.

A more centrally concentrated mm emission with respect to the optical may be due to the effect of extinction on the blue radiation toward the central regions of the galaxies. This indication agrees with recent reinterpretations of the optical galaxy profiles which seem to show non negligible light absorptions in the galaxy cores (Valentijn, 1990 and 1991; Davies, 1990).

Conclusions

Our knowledge of galaxy spectra in the submm band is still subject to relevant uncertainties. Should galaxy sizes at such wavelengths be comparable, or even larger, than those in the optical light, then mm emission and the corresponding amount of cold dust in the interstellar material would be significantly larger than expected. Detailed observations are planned to clarify this issue.

Several important consequences can be envisaged.

(A) Since the millimetric flux is proportional to the dust mass emitting at these energies, the amount of cold material in galaxies could have been underestimated. This fact could lower the gas-to-dust ratio ($< \frac{M_{gas}}{M_{dust}} >_{\text{spirals}} = 570 \pm 50$) claimed for spirals from CO and far-IR measurements (Young et al., 1989), to values comparable to that observed in the ISM of the Galaxy ($< \frac{M_{gas}}{M_{dust}} >_{\text{ISM}}$ is roughly 100).

(B) The contribution of discrete sources to the fluctuations of the Cosmic Microwave Background at small and intermediate scales is strongly sensitive to the galaxy spectra in the long wavelength spectral domain (Franceschini et al., 1989). An enhanced thermal dust emission from normal galaxies with respect to current estimates would eventually prevent detections of any intrinsic anisotropies of the CMB.

(C) More precise definitions of galaxy spectral energy distributions and local luminosity function would allow to improve the estimates of number counts and contributions to the diffuse background. Observations by FIRAS on COBE would eventually detect such a background.

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Centrefold
THE ROSETTA NEBULA

The "Rosetta Nebula" is situated just north of the celestial equator, in the constellation of Monoceros (the Unicorn). In its middle is the stellar cluster NGC 2244, one of the youngest of its kind known. The distance to the nebula and the cluster is about 4000–5000 light-years.

There is little doubt that the young stars – they are probably less than 1 million years old – were born in the Rosetta Nebula and have only recently become visible. This is because they have blown away the gas and dust from their immediate surroundings.

The Rosetta Nebula displays a number of dark lanes which are caused by the shadowing effect of dust clouds. Its red colour is caused by the light emission of hydrogen atoms and the different colour hues reflect local variations in the temperature and composition of the nebula.

This photo is a composite from three black-and-white photos obtained with the ESO 1-m Schmidt telescope at La Silla. Observer: D. Block; photographic work: C. Madsen.